# CAAP Annual Report

Date of Report: *January 19, 2017*

Contract Number: *DTPH56-14-H-CAP02*

Prepared for: *DOT*

Project Title: *Wall Break-through in Composite Repaired Defects*

Prepared by: *The University of Tulsa*

Contact Information: *Michael W. Keller, mwkeller@utulsa.edu, 918-631-3198*

For quarterly period ending: *January 10, 2017*

## Business and Activity Section

### (a) Generated Commitments

There has been no change in project participants or other contracts.

| Supplies Purchased | Cost |
|---|---|
| Testing supplies/Freeze protection | $544.38 |
| Freeze Protection/Testing Supplies | $651.04 |
| Sandblasting/Testing supplies | $120.92 |
| Testing Supplies/valves/pumps/hoses | $358.97 |

### (b) Status Update of Past Quarter Activities

During the past quarter, we have completed the following research tasks

1. Completed the experimental testing phase of the project.
2. Begun compiling DIC behavior of the various flaw shapes studied in the project.
3. Continuing our FEA modeling of the repairs.

### Elliptical Flaws on Straight Samples

Based on the repair response of the elbows, we decided that the effect of ellipticity on the repair response needed to be studied. Forming circular flaws in the elbows was impractical and the added complexity of the curved shape of the repair and the substrate also complicated the comparison of the flaw shape. Producing elliptical flaws inside the straight pipe was challenging and required a manual grinding process to remove material after an initial erosion. However, based on the narrow distribution of results, with respect to failure pressure, we are confident that this flaw can be formed repeatably.

Figure 1 shows the failure pressures of the straight pipe tests that have been conducted during this study. From this data, the drilled and eroded flaws appear to have statistically similar failure pressures when only the valid tests are averaged. A valid test is one where the leakage occurs out the end of the repair, signifying that the failure was interfacial and not due to a pinhole leak through the repair.

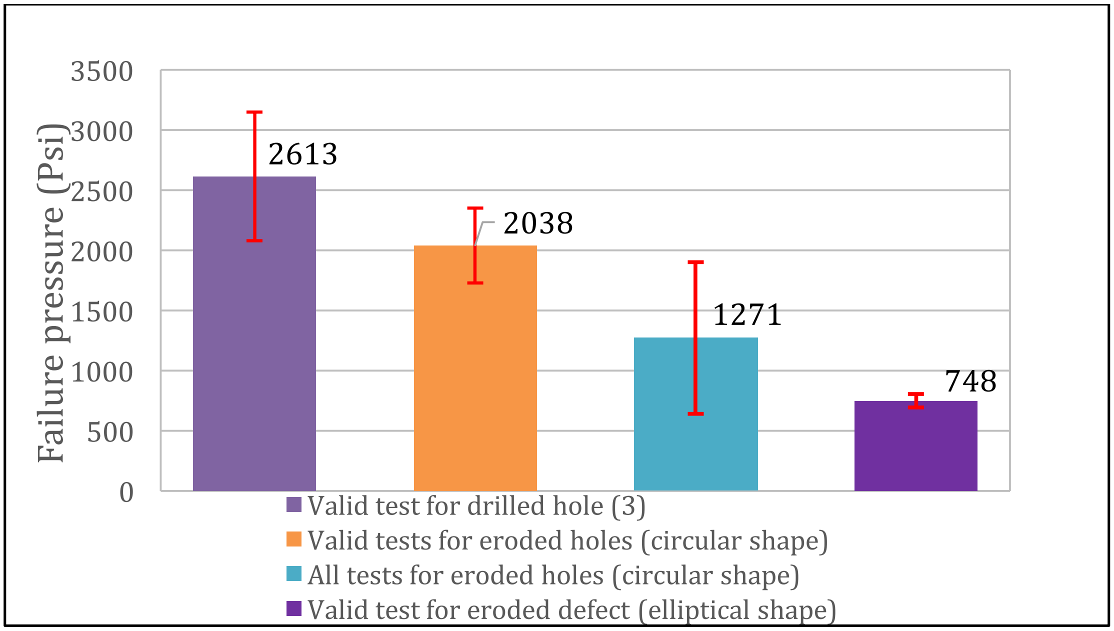


**Figure 1: Failure pressures measured for three flaw types in this study.**

If we include all tests on eroded flaws that have been performed, the failure pressures are significantly lower and there is a difference in performance between the drilled and the eroded specimens. There is some anecdotal evidence that there is a higher probability of non-valid, through-repair failures for the eroded flaws due to a higher strain in the repair over the flaw. This appears to be true for elbows and we will discuss this more in the section below.

However, when we moved to flaws with significant ellipticity, while maintaining the same, circular through-wall defect, failure pressures are much lower. In the specimens in Figure 1, the elliptical eroded flaws had an axial extent of 11 times the diameter of the through-wall penetration. For these tests the failure pressures were less than half of the pressures of drilled specimens. Even though the through-wall penetration in these specimens are near circular and of the same diameter, the ellipticity plays a major role in the failure. Based on our post-mortem inspection of the specimens, we have found that elliptical-flaw specimens appear to "buckle in." We have observed similar behavior in our FEA studies, but had not yet observed this behavior in experiments until now. Currently, PCC-2 offers no guidance on flaws with circular through-wall penetrations that also have significant elliptical damage. The axial flaw predictions used in PCC-2 appear to be sufficiently conservative that they might be adapted as design guidance. We are working on understanding the behavior of these elliptical flaws in order to determine if proposing that axial flaw models be adopted for this type of damage.

**DIC Analysis**

In addition to the testing described above, we are working through our DIC data to compile complete comparison plots for the tests that have been run during this study. As we have mentioned in previous reports, we are interested in comparing two main measurements. The out-of-plane displacement above the flaw and the surface strain over the flaw. The out-of-plane displacements help to determine if the underlying design model in PCC-2 is valid. The strains allow us to understand the local performance of the repair and determine if our anecdotal evidence of more through-repair failures in eroded specimens is correlated with measurable differences in strain levels.

For the analysis discussed below, the strains were extracted along the centerline of the flaw for an elbow specimen. Figure 2 shows an example DIC image with the extraction line indicated.

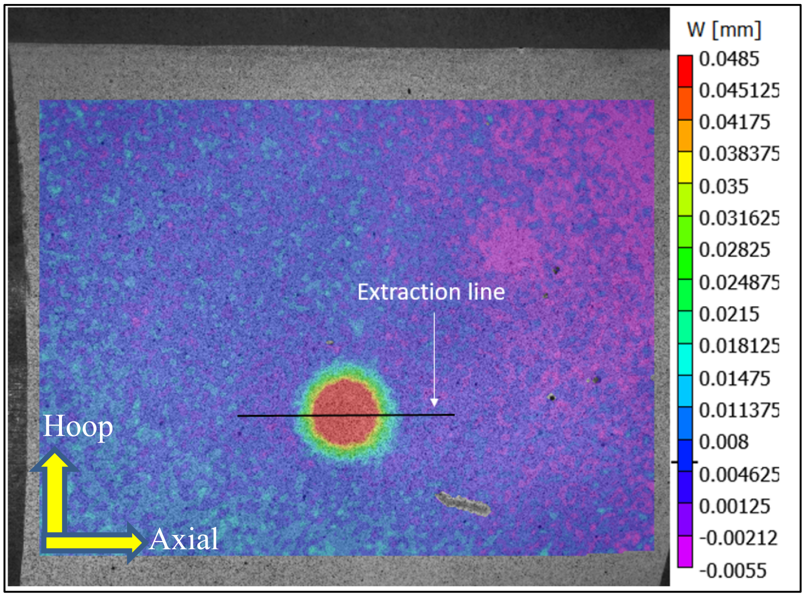


**Figure 2: DIC image of repaired pipe showing extraction line along the axis of the specimen.**

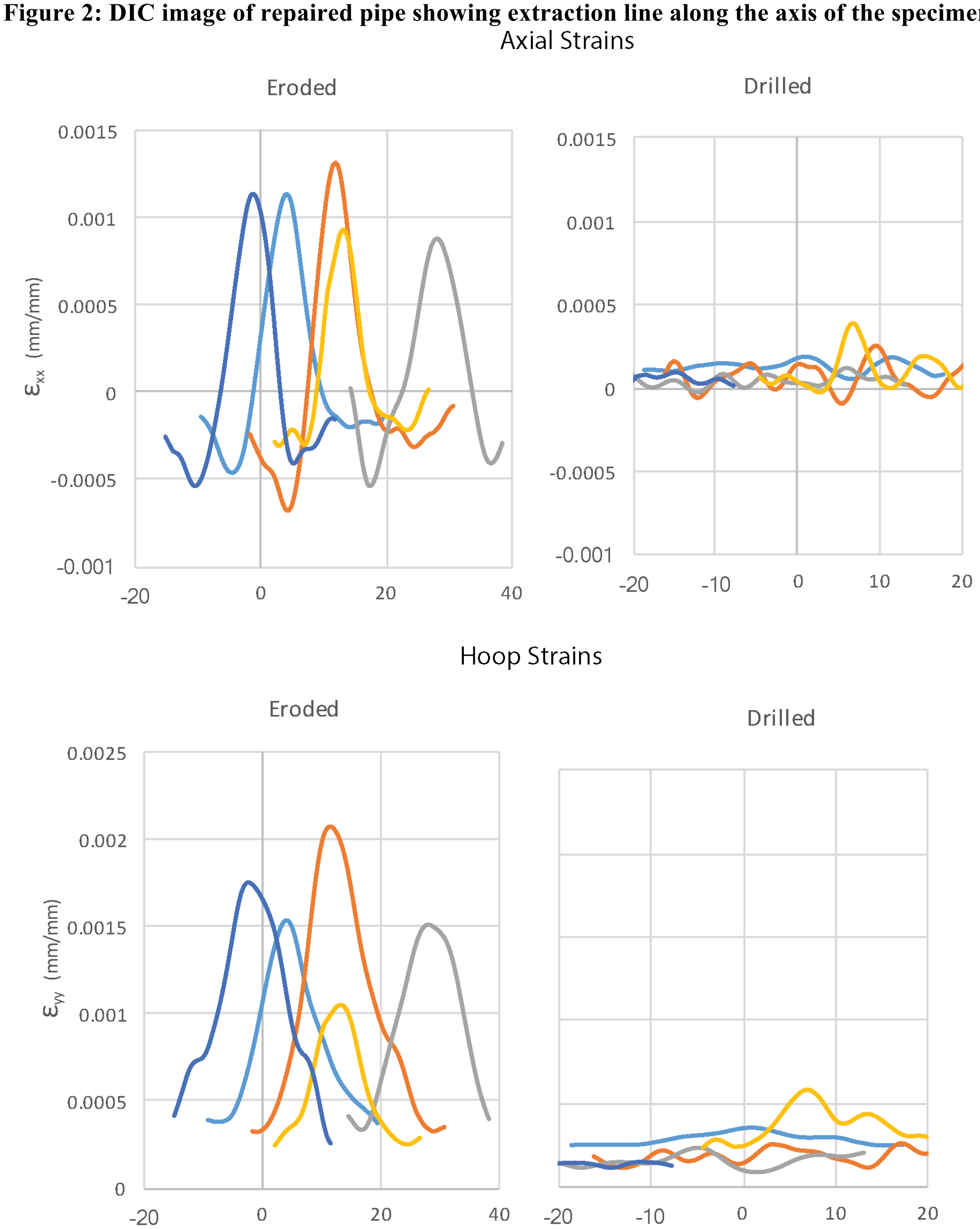


**Figure 3: Extracted strains for eroded and drilled flaws at 1000 psi internal pressure. The peak offsets have no physical meaning and are introduced to enhance data clarity.**

Figure 3 shows the hoop and axial strains that were extracted from tests on repaired elbow specimens. This figure clearly demonstrates the difference in strain between the eroded flaws and the drilled flaws. For the elbows, there was a significant difference in failure pressures between eroded and drilled flaws, with eroded flaws failing at much lower pressures. This trend is clearly predicted by the surface strains in Figure 3. For the straight specimens, the strains were nearly identical for the drilled and eroded flaws, which correlated to the smaller difference in failure pressures between the two specimens (see Figure 1). We are continuing to analyze this data to help understand the observed failure behavior among all the tests that have been performed.

**(c) Description of any Problems/Challenges**

The major issue we had during the last semester was dealing with a move to a non-heated test facility due to the requirements for the large-scale tests that are ongoing in the other projects. This required some freeze protecting of the test facility due to the cold weather. This has been completed and we were able to continuing testing. We also had some minor equipment failures during this period as well that required the replacement of some valves and other associated items. These are complete and we have essentially completed the experimental testing phase of this project at this point. One of the biggest challenges was the recognition that there are some issues with the boundary conditions in some of our FEA simulations that have been completed. There is a “kinking effect” that is showing up in our simulations, which is giving us non-physical boundary behavior. We are running new simulations to address these issues and correct the problem.

***(d)* Planned Activities for the Next Quarter –**

Planned activities for the next quarter include the following

1. Continue FEA modeling
2. Write final report.
3. Begin compiling design guidance for presentation to PCC committee.